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(JMTBA/JSA)

**Test conditions for testing the accuracy
of boring and milling machines with
horizontal spindle — Part 1: Machines
with fixed column and movable table**

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee according to the proposal for establishment of Japanese Industrial Standard submitted by Japan Machine Tool Builders' Association (JMTBA)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law.

The corresponding International Standards, **ISO 3070** series, were revised and divided into Part 1 to Part 3 in 2007 from previous 4 parts including Part 0 (General). **JIS B 6210**, **JIS B 6222** and **JIS B 6252** have been the standards corresponding to the previous series; and at this time of revision, these three standards are restructured, and established as Part 1 to Part 3 of **JIS B 6210**.

Consequently **JIS B 6210:1998** has been withdrawn and replaced with this Standard.

This **JIS** document is protected by the Copyright Law.

Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public.

JIS B 6210 series consists of the following 3 parts under the general title “*Test conditions for testing the accuracy of boring and milling machines with horizontal spindle*”:

Part 1: Machines with fixed column and movable table

Part 2: Machines with movable column and fixed table

Part 3: Machines with movable column and movable table

Test conditions for testing the accuracy of boring and milling machines with horizontal spindle — Part 1 : Machines with fixed column and movable table

Introduction

This Japanese Industrial Standard has been prepared based on the third edition of **ISO 3070-1** published in 2007 with some modifications of the technical contents to aid users in understanding this Standard.

The portions given dotted underlines are the matters in which the contents of the original International Standard have been modified. A list of modifications with the explanations is given in Annex JA.

1 Scope

This Standard specifies, with reference to **JIS B 6190-2**, **JIS B 6190-7** and **JIS B 6191**, geometric tests, machining tests and tests for checking the accuracy and repeatability of positioning by numerical control of the general-purpose and normal-accuracy boring and milling machines with horizontal spindle having fixed column and movable table. This Standard also specifies the tolerances corresponding to these tests.

This type of machine can be provided with spindle heads of different types, such as those with boring spindle and milling spindle, boring spindle and facing head, or ram.

This Standard concerns machines having table saddle movement (Z-axis), table movement (X-axis), spindle head movement (Y-axis), movement of boring spindle or ram (W-axis) and possibly facing head slide movement (U-axis), that may include the index table and the rotary table.

NOTE : In **JIS B 6210-2** and **JIS B 6210-3**, the movement of spindle or ram is designated as Z-axis movement.

This Standard deals only with the verification of the accuracy of the machine. It does not apply to the operational testing of the machine (e.g. vibration, abnormal noise, stick-slip motion of components) nor to machine characteristics (e.g. spindle speed, feed speed), as such checks are generally carried out before testing the accuracy.

NOTE : The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 3070-1 : 2007 *Machine tools — Test conditions for testing the accuracy of boring and milling machines with horizontal spindle — Part 1 : Machines with fixed column and movable table* (MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to

ISO/IEC Guide 21-1.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. For standards indicated below, only the editions of the indicated year shall be applied and any revisions (including amendments) made thereafter shall not be applied.

JIS B 6190-2 : 2008 *Test code for machine tools — Part 2 : Determination of accuracy and repeatability of positioning numerically controlled axes*

NOTE : Corresponding International Standard : **ISO 230-2** : 2006 *Test code for machine tools — Part 2 : Determination of accuracy and repeatability of positioning numerically controlled axes* (IDT)

JIS B 6190-7 : 2008 *Test code for machine tools — Part 7 : Geometric accuracy of axes of rotation*

NOTE : Corresponding International Standard : **ISO 230-7** : 2006 *Test code for machine tools — Part 7 : Geometric accuracy of axes of rotation* (IDT)

JIS B 6191 : 1999 *Machine tools — Geometric accuracy tests and practical tests — Test methods*

NOTE : Corresponding International Standard : **ISO 230-1** : 1996 *Test code for machine tools — Part 1 : Geometric accuracy of machines operating under no-load or finishing conditions* (MOD)

ISO 1101 : 2004 *Geometrical Product Specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

3 Terminology and designation of axes

3.1 General

A boring and milling machine with horizontal spindle is a machine tool in which the principal cutting motion is the rotation of the cutting tool against the non-rotating workpiece and where the cutting energy is brought by the cutting tool rotation.

The principal cutting motion is generated by the rotation of the spindle(s) and, possibly, of the facing head.

3.2 Types of movement

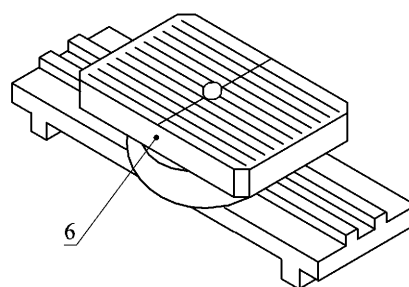
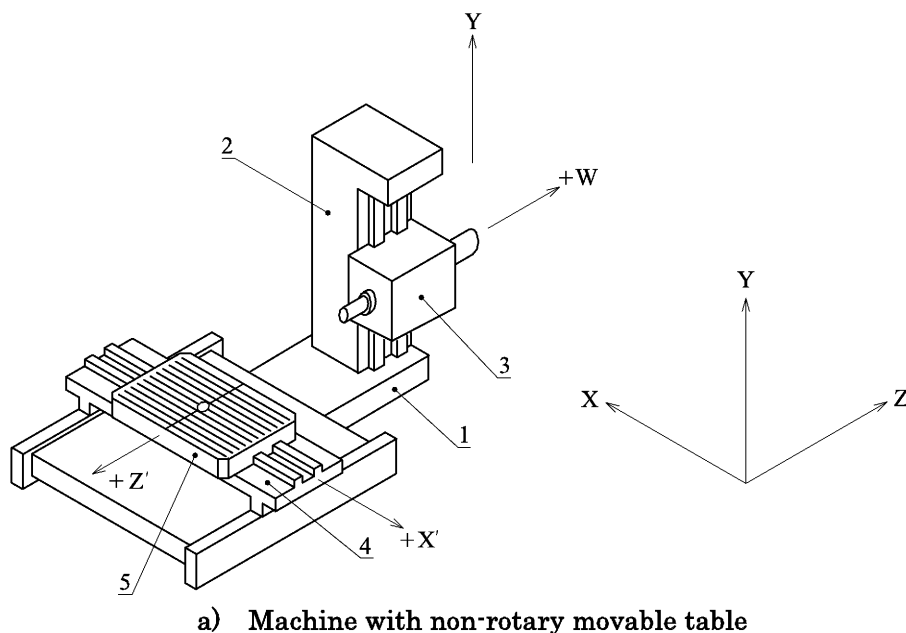
The feed movements are as follows.

- a) Z-axis direction feed of table saddle, X-axis direction feed of table, and possibly B-axis direction feed
- b) Y-axis direction feed of spindle head
- c) W-axis direction feed of spindle
- d) U-axis direction feed of facing head slide, possibly

Designations of structural components of machines shown in figure 1 are given in table 1. Two configurations of the boring and milling machine with horizontal spindle are given in figure 1. The machine with non-rotary movable table is shown in **a)** and that with integral rotary table is shown in **b)** of figure 1.

Table 1 Designations (see figure 1)

Reference No.	Designation
1	Bed
2	Column
3	Spindle head
4	Table saddle
5	Table
6	Index or rotary table



NOTE 1 In this Standard, the designation of axis different from that in JIS B 6310 is used.

NOTE 2 For No. 1 to No. 6, see table 1.

Figure 1 Table types of boring and milling machine with horizontal spindle

4 Machining operations by boring and milling machine with horizontal spindle

4.1 Boring operation

Boring is an operation for machining holes of various sizes and geometries in which the principal cutting movement is the rotation of a single-point cutting tool against the non-rotating workpiece and where the cutting energy is brought by the rotation of the cutting tool.

Boring the diameter of cylindrical, conical, blind or through holes to the required size is achieved by using a boring bar to locate the cutting edge of the boring tool in a well-defined position with respect to the axis average line of the boring spindle.

In the case of coaxial bores situated on opposite faces of the same workpiece, the machining operation is carried out using a boring bar which is supported between the machine boring spindle and the steady block located on the other side of the table.

Alternatively, if the machine has a rotary table, such an operation can be carried out by rotating the table 180° to bore the opposite side of the workpiece with the same boring tool located on the boring bar that is mounted on the boring spindle without any steady support (reverse boring). Although more economical, this alternative method requires higher accuracy for table angular positioning as well as for the axis of rotation errors.

4.2 Milling operation

Milling is an operation for machining non-axisymmetrical (non-rotational) surfaces of various geometries in which the principal cutting motion is the rotation of a cutting tool with multiple cutting edges against the non-rotating workpiece, and where the cutting energy is brought by the cutting tool rotation.

Milling operations mostly involve face milling and end milling. The tools are mounted either in the boring spindle taper (see figure 2) or on the milling spindle nose as for face milling cutters.

5 Principle elements

5.1 Spindle head

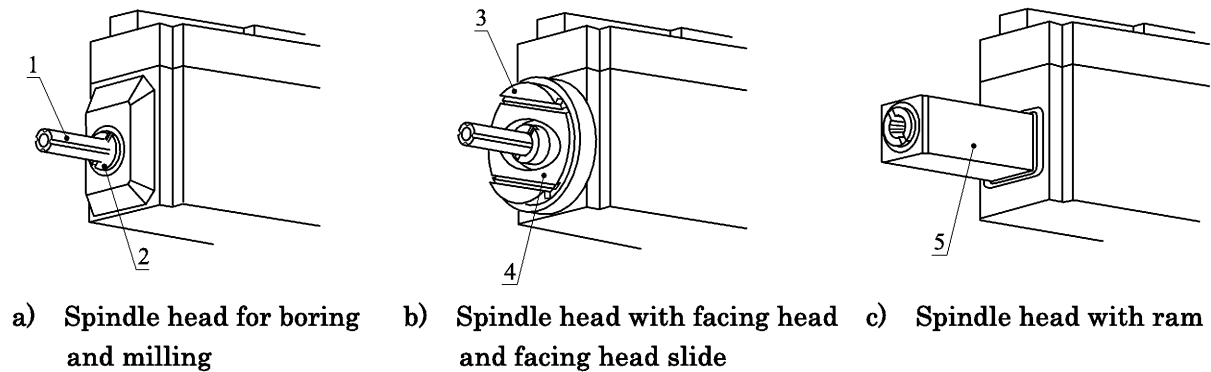
Examples of various types of spindle head are given in figure 2. Designations of principle elements are given in table 2.

The facing head generally has a facing head slide, and is either integral or removable ; the latter is considered as an accessory.

It should be noted that the integral facing head may not always be mounted onto the milling spindle and may have its own bearing independent from the main spindle bearing.

Table 2 Designations (see figure 2)

Reference No.	Designation
1	Boring spindle
2	Milling spindle
3	Facing head
4	Facing head slide
5	Ram



NOTE : For No. 1 to No. 5, see table 2.

Figure 2 Types of spindle head

5.2 Table

Tables may have various rectilinear and rotary movements for positioning and feed.

The two main rectilinear movements, the directions of which are perpendicular to each other, are used either for positioning the table or giving the specified feed of workpiece.

The rotary movement of the table is used for the following.

- a) Angular positioning in the plane of table rotation
- b) Circular feed of workpiece for milling
- c) Circular cutting feed for turning operation

5.3 Steady block

Due to the decreasing of practical machining using long boring bars, the steady block may be treated as optional parts or accessories.

6 General

6.1 Measuring units

In this Standard, all linear dimensions, deviations and corresponding tolerances are expressed in millimetres (mm) and angular dimensions are expressed in degrees (°). Angular deviations and the corresponding tolerances are generally expressed in ratio of length (e.g., 0.00x/1 000) ; however, microradians (μrad) or arcseconds (") may be used.

The equivalence of these expressions is as follows.

$$0.010/1\ 000 = 10 \times 10^{-6} = 10\ \mu\text{rad} \approx 2''$$

6.2 Reference to JIS B 6190 (series) and JIS B 6191

In applying this Standard, reference shall be made to **JIS B 6191**, especially for the installation of the machine before testing, warming up of the spindle and other moving components, measuring methods, and the accuracy of measuring instruments.

In the "Observations" block of each test description, corresponding clause or sub-clause of **JIS B 6190-2**, **JIS B 6190-7** or **JIS B 6191** to the test is shown.

6.3 Testing sequence

The sequence in which the tests are presented in this Standard in no way defines the practical order of testing. In order to make the mounting of measuring instruments or gauging easier, tests may be carried out in any order.

6.4 Tests to be carried out

When testing a machine, it is not always necessary to carry out all the tests described in this Standard. The purchaser may choose tests of interest according to the agreement with the manufacturer. These tests are to be clearly stated when ordering a machine. The mere reference to this Standard for the acceptance tests, without specifying the tests carried out or without agreement on the relevant expenses, cannot be considered binding for any contract between the purchaser and the manufacturer.

6.5 Measuring instruments

The measuring instruments indicated in the following sections are examples only.

Other instruments capable of measuring the same quantities and having the same, or a smaller, measuring uncertainty may be used. Linear displacement sensors shall have a resolution of 0.001 mm or better.

6.6 Machining tests

The machining tests shall be made with finishing cuts only, not with roughing cuts, which are liable to generate appreciable cutting forces.

6.7 Software compensation

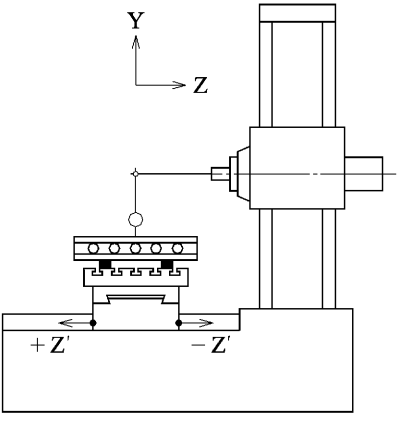
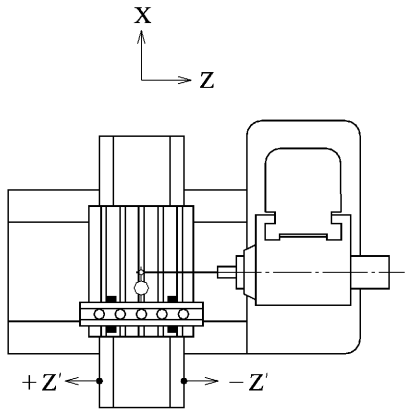
When built-in software facilities are available for compensating geometric, positioning, contouring and thermal deviations, their use during these tests should be upon the agreement between the purchaser and the manufacturer. When the software compensation is used, this shall be stated in the test report.

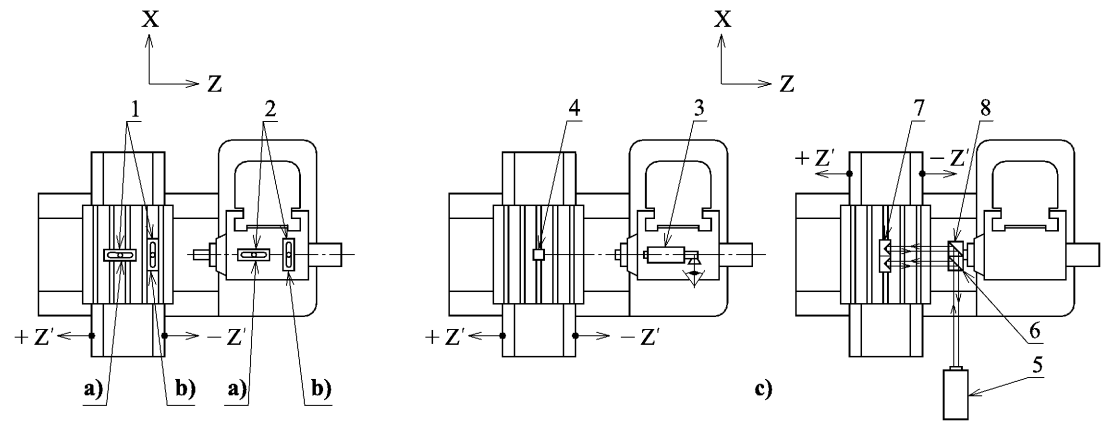
6.8 Minimum tolerance

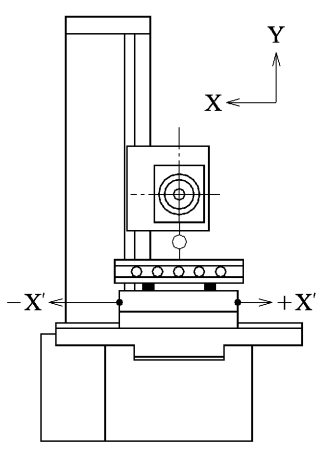
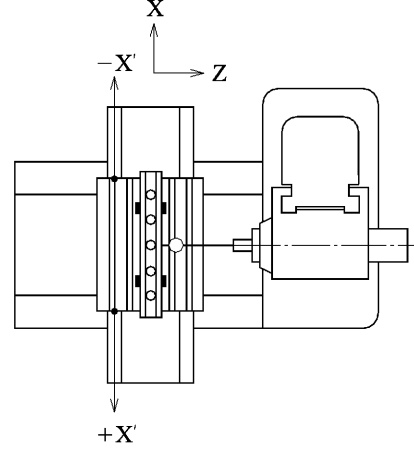
When determining the tolerance on the measuring length which is different from that given in this Standard (see 2.311 of **JIS B 6191**), it shall be taken into consideration that the minimum value of tolerance is 0.005 mm.

7 Geometric tests

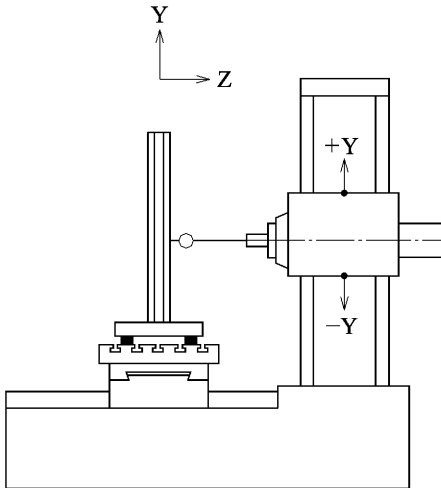
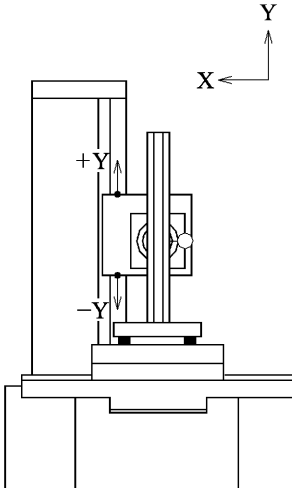
7.1 Straightness and angular deviation of linear axes

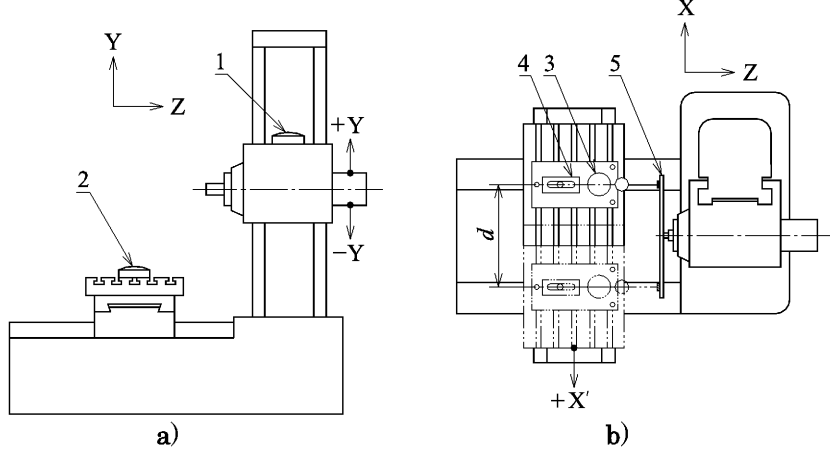
Object Checking of straightness of table saddle movement (Z-axis) a) In YZ plane (EYZ) b) In ZX plane (EXZ)	G1
Diagram   a) b)	
Tolerance a) and b) 0.02 for measuring lengths up to 1 000 0.03 for measuring lengths above 1 000 Local tolerance: 0.006 for any measuring length of 300	Measured deviation a) b)
Measuring instruments Straightedge, linear displacement sensor and gauge blocks, or optical measuring instruments	
Observations and references to JIS B 6191 5.232.11, 5.232.12 and 5.232.13 The table shall be locked in mid-travel in the X-axis direction, and the spindle head shall be locked in mid-travel as close as possible. The reference face of straightedge shall be set on the table a) vertically and b) horizontally parallel to the table saddle movement (Z-axis) (parallel means that the readings of the linear displacement sensor touching the straightedge at both ends of the movement are the same value). If the spindle can be locked, the linear displacement sensor shall be mounted on it; if not, the linear displacement sensor shall be mounted on the spindle head. The stylus of linear displacement sensor shall be applied normal to the reference face of straightedge. The table saddle shall be travelled in the Z-axis direction and the readings shall be recorded.	

Object Checking of angular deviation of table saddle movement (Z-axis) a) In YZ plane (EAZ : pitch) b) In XY plane (ECZ : roll) c) In ZX plane (EBZ : yaw)	G2
Diagram  1 Precision level for measurement 2 Precision level for reference 3 Autocollimator 4 Mirror 5 Laser head 6 Interferometer 7 Mirror for measuring angular deviation 8 Beam bender	
Tolerance a), b) and c) 0.04/1 000 Local tolerance: 0.02/1 000 for any measuring length of 300	Measured deviation a) b) c)
Measuring instruments a) Precision level, laser interferometer or other optical angular deviation measuring instruments b) Precision level c) Laser interferometer or other optical angular deviation measuring instruments	
Observations and references to JIS B 6191 5.231.3 and 5.232.2 The precision level for measurement or mirror shall be set on the table. a) In Z-axis direction (set vertically for an autocollimator) b) In X-axis direction c) In Z-axis direction (set horizontally for an autocollimator) The precision level for reference shall be set on the spindle head, and the spindle head shall be set in mid-travel. When the table saddle movement (Z-axis) causes the angular deviation on both spindle head and table, differential measurements of the two angular deviations shall be made respectively, and recorded. Measurements shall be carried out at a minimum of five positions equally spaced along the travel in both directions of the movement.	

Object Checking of straightness of table movement (X-axis) a) In XY plane (EYX) b) In ZX plane (EZX)	G3
Diagram   a) b)	
Tolerance a) and b) 0.02 for measuring lengths up to 1 000 0.01 is added for each 1 000 increase in measuring length above 1 000 Maximum tolerance: 0.05 Local tolerance: 0.006 for any measuring length of 300	Measured deviation a) b)
Measuring instruments Straightedge, linear displacement sensor and gauge blocks, or optical measuring instruments	
Observations and references to JIS B 6191 5.232.11 and 5.232.13 The table saddle shall be locked in mid-travel in the Z-axis direction, and the spindle head shall be locked in mid-travel as close as possible. The reference face of straightedge shall be set on the mid-table a) vertically and b) horizontally parallel to the table movement (X-axis) (parallel means that the readings of the linear displacement sensor touching the straightedge at both ends of the movement are the same value). If the spindle can be locked, the linear displacement sensor shall be mounted on it; if not, the linear displacement sensor shall be mounted on the spindle head. The stylus of linear displacement sensor shall be applied normal to the reference face of straightedge. The table shall be travelled in the X-axis direction and the readings shall be recorded.	

Object		G4	
Checking of angular deviation of table movement (X-axis)			
a) In XY plane (ECX: pitch)			
b) In YZ plane (EAX: roll)			
c) In ZX plane (EBX: yaw)			
Diagram			
1	Precision level for measurement	5	Laser head
2	Precision level for reference	6	Interferometer
3	Autocollimator	7	Mirror for measuring angular deviation
4	Mirror	8	Beam bender
Tolerance		Measured deviation	
a), b) and c)		a)	
0.04/1 000		b)	
Local tolerance: 0.02/1 000 for any measuring length of 300		c)	
Measuring instruments			
a) Precision level, laser interferometer or other optical angular deviation measuring instruments			
b) Precision level			
c) Laser interferometer or other optical angular deviation measuring instruments			
Observations and references to JIS B 6191			
5.231.3 and 5.232.2			
The precision level for measurement or mirror shall be set on the table.			
a) In X-axis direction (set vertically for an autocollimator)			
b) In Z-axis direction			
c) In X-axis direction (set horizontally for an autocollimator)			
The precision level for reference shall be set on the spindle head, and the spindle head shall be set in mid-travel.			
When the table movement (X-axis) causes an angular deviation on both spindle head and table, differential measurements of the two angular deviations shall be made respectively, and recorded.			
Measurements shall be carried out at a minimum of five positions equally spaced along the travel in both directions of the movement.			

Object Checking of straightness of spindle head movement (Y-axis) a) In YZ plane (EZY) b) In XY plane (EXY)	G5
Diagram   a) b)	
Tolerance a) and b) 0.02 for any measuring length of 1 000	Measured deviation a) b)
Measuring instruments Cylindrical square, surface plate, linear displacement sensor and adjustable blocks, or optical measuring instruments	
Observations and references to JIS B 6191 5.232.11 The reference face of cylindrical square shall be set on the table parallel to the spindle head movement (Y-axis) (parallel means that the readings of the linear displacement sensor touching the cylindrical square at both ends of the movement are the same value). The table and the table saddle shall be locked in mid-travel. If the spindle can be locked, the linear displacement sensor shall be mounted on it; if not, the linear displacement sensor shall be mounted on the spindle head. a) The stylus of linear displacement sensor shall be applied to the cylindrical square parallel to the Z-axis direction, and the spindle head shall be travelled in the Y-axis direction through the measuring length. b) The stylus of linear displacement sensor shall be applied to the cylindrical square parallel to the X-axis direction, and the procedure same as above shall be carried out.	

Object Checking of angular deviation of spindle head movement (Y-axis) a) In YZ plane (EAY) b) In ZX plane (EBY)		G6
Diagram  1 Precision level for measurement 4 Precision level 2 Precision level for reference 5 Special jig 3 Cylindrical square		
Tolerance a) and b) $Y \leq 4\,000 : 0.04/1\,000$ $Y > 4\,000 : 0.06/1\,000$		Measured deviation a) b)
Measuring instruments a) Precision level, laser interferometer or other optical angular deviation measuring instruments b) Surface plate, cylindrical square, precision level, linear displacement sensors and special jig		

Observations and references to JIS B 6191**5.231.3 and 5.232.2**

- a) The precision level for measurement shall be set on the spindle head parallel to the Z-axis direction. The precision level for reference shall be set on the table in the same direction.

When the Y-axis movement causes an angular deviation on both spindle head and table, differential measurements of the two angular deviations shall be made respectively, and recorded.

- b) The surface plate shall be mounted on the table and adjusted so that its upper surface is levelled.

The cylindrical square shall be set on the surface plate so that the stylus of linear displacement sensor locked on a special jig mounted on the spindle nose touches the cylindrical square.

The precision level shall be set also on the surface plate parallel to the Z-axis direction. The spindle head shall be travelled (Y-axis) and the readings at respective measuring positions shall be recorded.

Then, the table shall be travelled distance d , and the linear displacement sensor shall be mounted again so that the stylus touches the cylindrical square.

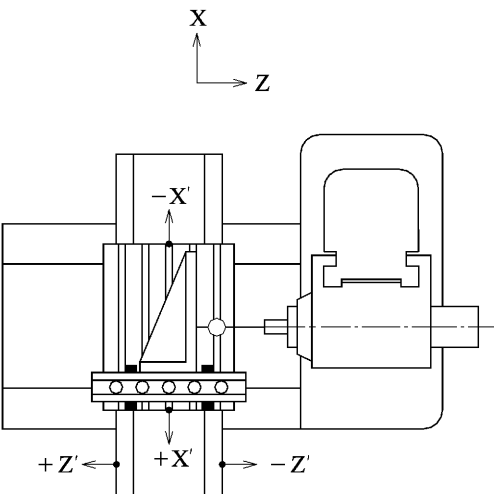
When the level shows different values because of the roll in table movement, the level of the surface plate shall be adjusted to the same position as that of the first position, then readings shall be recorded at the same measuring positions.

For each measuring position, the differences between two readings shall be obtained, and the difference between maximum and minimum divided by distance d shall be deemed as the angular deviation.

Measurements shall be carried out at a minimum of five positions equally spaced along the travel in both directions of up and down movements.

NOTE : The levelling difference between two locations of the table directly influences the measurement results.

7.2 Squareness between linear axes

Object Checking of squareness between table movement (X-axis) and table saddle movement (Z-axis)	G7
Diagram 	
Tolerance 0.02 for any measuring length of 500	Measured deviation
Measuring instruments Straightedge, square and linear displacement sensor	
Observations and references to JIS B 6191 5.522.4 The spindle head shall be locked in mid-travel as close as possible. The reference face of straightedge shall be set on the table, parallel to the table saddle movement (Z-axis), and the square shall be pressed against straightedge (parallel means that the readings of the linear displacement sensor touching the straightedge at both ends of the movement are the same value). The table saddle shall be locked in mid-travel. If the spindle can be locked, the linear displacement sensor shall be mounted on it; if not, the linear displacement sensor shall be mounted on the spindle head. The stylus of linear displacement sensor shall be applied to the reference face of square. The table shall be travelled in the X-axis direction and the readings shall be recorded. NOTE : This measurement may be carried out by directly applying the stylus of linear displacement sensor to the two reference faces of the square without using a straight-edge.	